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Spitzer Mid-Infrared Imaging of Nearby Ultraluminous Infrared Galaxies

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Abstract. We have observed 14 nearby ($z < 0.16$) Ultraluminous Infrared Galaxies (ULIRGs) with *Spitzer* at 3.6—24μm. The underlying host galaxies are well-detected, in addition to the luminous nuclear cores. While the spatial resolution of *Spitzer* is poor, the great sensitivity of the data reveals the underlying galaxy merger remnant, and provides the first look at off-nuclear mid-infrared activity.

1. Background

ULIRGs as a class are characterized by $L_{ir} > 10^{12} L_{\odot}$, equivalent to the luminosity of classical optically selected quasars. Based on extensive ground and space-based imaging, nearly all are known to be advanced merger remnants resulting from collisions of gas-rich galaxies. Dynamics of the collision result in a rearrangement of the gas, dust, and stellar content of the galaxies. The rapid inflow of gas deep into the merger core results in a powerful burst of star formation, and/or the fueling (in at least one-quarter) of an active nucleus. It has been postulated that ULIRGs are the progenitors of both QSOs and elliptical galaxies. Extensive imaging campaigns in the UV, optical, near and mid-IR during the '90s revealed the complex composite nature of the ULIRGs (Surace et al. 2000, Scoville et al. 2000, Soifer et al. 2000, Goldader et al. 2002). At optical/UV wavelengths the emission is dominated by the old stellar population, as well as actively star-forming "super star clusters" located both in the nuclear regions and along the tidal features. At infrared wavelengths the emission is increasingly due to thermal dust emission arising in a compact core typically less than 100pc in diameter. Ground-based mid-infrared observations constrained a large fraction of the IRAS 12 and 25μm emission to an unresolved core.

2. *Spitzer* Mid-IR Imaging

As part of the IRAC GTO program, we observed 14 nearby ULIRGs selected from the well-studied Bright Galaxy and Warm Galaxy Samples of Sanders et al. (1988). The spatial resolution of Spitzer is relatively poor ($\approx 2''$) at IRAC wavelengths compared to the known optical compact structure in these galaxies. However, it can resolve the galaxy bodies and extended tidal features, and separate the known double nuclei in some systems. While ground-based observations (e.g. from Keck) offer several times higher spatial resolution, they lack the sensitivity to detect anything beyond the high surface brightness nuclei. The extended, and hence potentially resolvable, emission is too faint to be readily

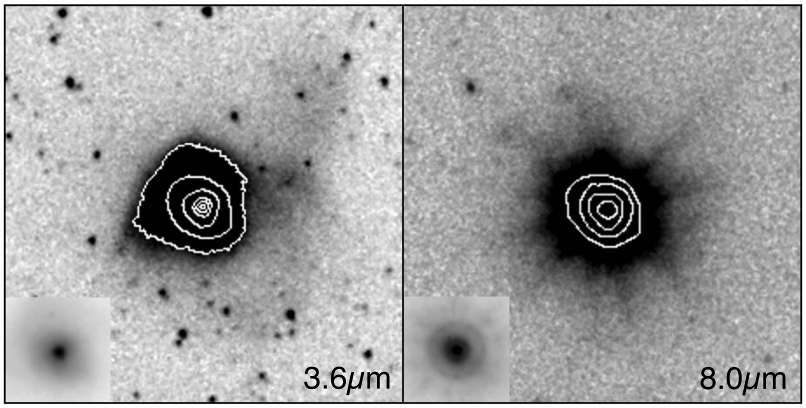

Figure 1. **Arp 220**, the nearest ULIRG. Shown with a logarithmic scale, the 3.6μm image clearly shows the extended galaxy body. At 8μm the underlying emission from the host galaxy is detected as a faint extended component, but the system is increasingly dominated by a high surface brightness region unresolved by *Spitzer* that contributes $\approx$2/3 of the total flux in the IRAC filter. The small insets show a linear stretch of the point-like nuclear core, at the same spatial scale as the larger images.

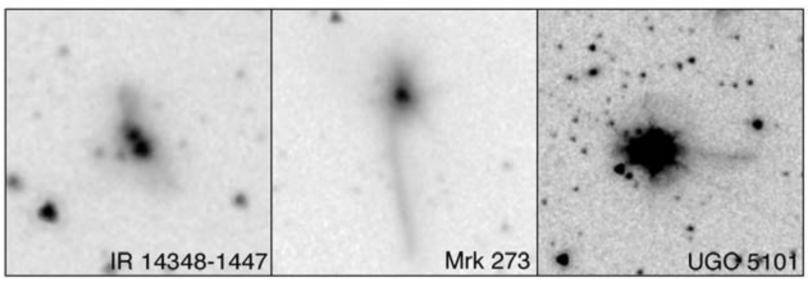

Figure 2. 3.6μm images of three selected ULIRGs. The galaxy bodies and tidal features, composed of stars, are clearly visible at this wavelength as are one or more compact nuclei.

detected from the ground. We therefore specifically selected systems that had optical emission on spatial scales of several arcseconds or more.

All of the galaxy bodies are well-detected at the shorter wavelengths, and appear very similar to previous optical and near-IR imaging. There is little evidence for extended emission (e.g. tidal features) beyond that previously known. At longer wavelengths the ULIRGs are increasingly dominated by the nuclear core, which is generally unresolved by *Spitzer*. Preliminary analysis suggests that the cores of the double nucleus systems appear more diffuse than the single nucleus systems. Further analysis will examine the colors of the galaxy bodies, in order to characterize the dust distribution and the state of star formation in the merger remnants.

References Goldader et al., 2002, ApJ, 568, 651; Sanders et al., 1988, ApJ, 325, 74; Sanders et al., 1988, ApJ, 328, 35; Scoville et al., 2000, AJ, 119, 991; Soifer et al., 2002, AJ, 124, 2980; Surace et al., 2000, ApJ, 529, 170